

## 5.2 Transportation And Marketing Of Petroleum Liquids<sup>1-3</sup>

### 5.2.1 General

The transportation and marketing of petroleum liquids involve many distinct operations, each of which represents a potential source of evaporation loss. Crude oil is transported from production operations to a refinery by tankers, barges, rail tank cars, tank trucks, and pipelines. Refined petroleum products are conveyed to fuel marketing terminals and petrochemical industries by these same modes. From the fuel marketing terminals, the fuels are delivered by tank trucks to service stations, commercial accounts, and local bulk storage plants. The final destination for gasoline is usually a motor vehicle gasoline tank. Similar distribution paths exist for fuel oils and other petroleum products. A general depiction of these activities is shown in Figure 5.2-1.

### 5.2.2 Emissions And Controls

Evaporative emissions from the transportation and marketing of petroleum liquids may be considered, by storage equipment and mode of transportation used, in four categories:

1. Rail tank cars, tank trucks, and marine vessels: loading, transit, and ballasting losses.
2. Service stations: bulk fuel drop losses and underground tank breathing losses.
3. Motor vehicle tanks: refueling losses.
4. Large storage tanks: breathing, working, and standing storage losses. (See Chapter 7, "Liquid Storage Tanks".)

Evaporative and exhaust emissions are also associated with motor vehicle operation, and these topics are discussed in AP-42 *Volume II: Mobile Sources*.

#### 5.2.2.1 Rail Tank Cars, Tank Trucks, And Marine Vessels -

Emissions from these sources are from loading losses, ballasting losses, and transit losses.

##### 5.2.2.1.1 Loading Losses -

Loading losses are the primary source of evaporative emissions from rail tank car, tank truck, and marine vessel operations. Loading losses occur as organic vapors in "empty" cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapors are a composite of (1) vapors formed in the empty tank by evaporation of residual product from previous loads, (2) vapors transferred to the tank in vapor balance systems as product is being unloaded, and (3) vapors generated in the tank as the new product is being loaded. The quantity of evaporative losses from loading operations is, therefore, a function of the following parameters:

- Physical and chemical characteristics of the previous cargo;
- Method of unloading the previous cargo;
- Operations to transport the empty carrier to a loading terminal;
- Method of loading the new cargo; and
- Physical and chemical characteristics of the new cargo.

The principal methods of cargo carrier loading are illustrated in Figure 5.2-2, Figure 5.2-3, and Figure 5.2-4. In the splash loading method, the fill pipe dispensing the cargo is lowered only part way into the cargo tank. Significant turbulence and vapor/liquid contact occur during the splash

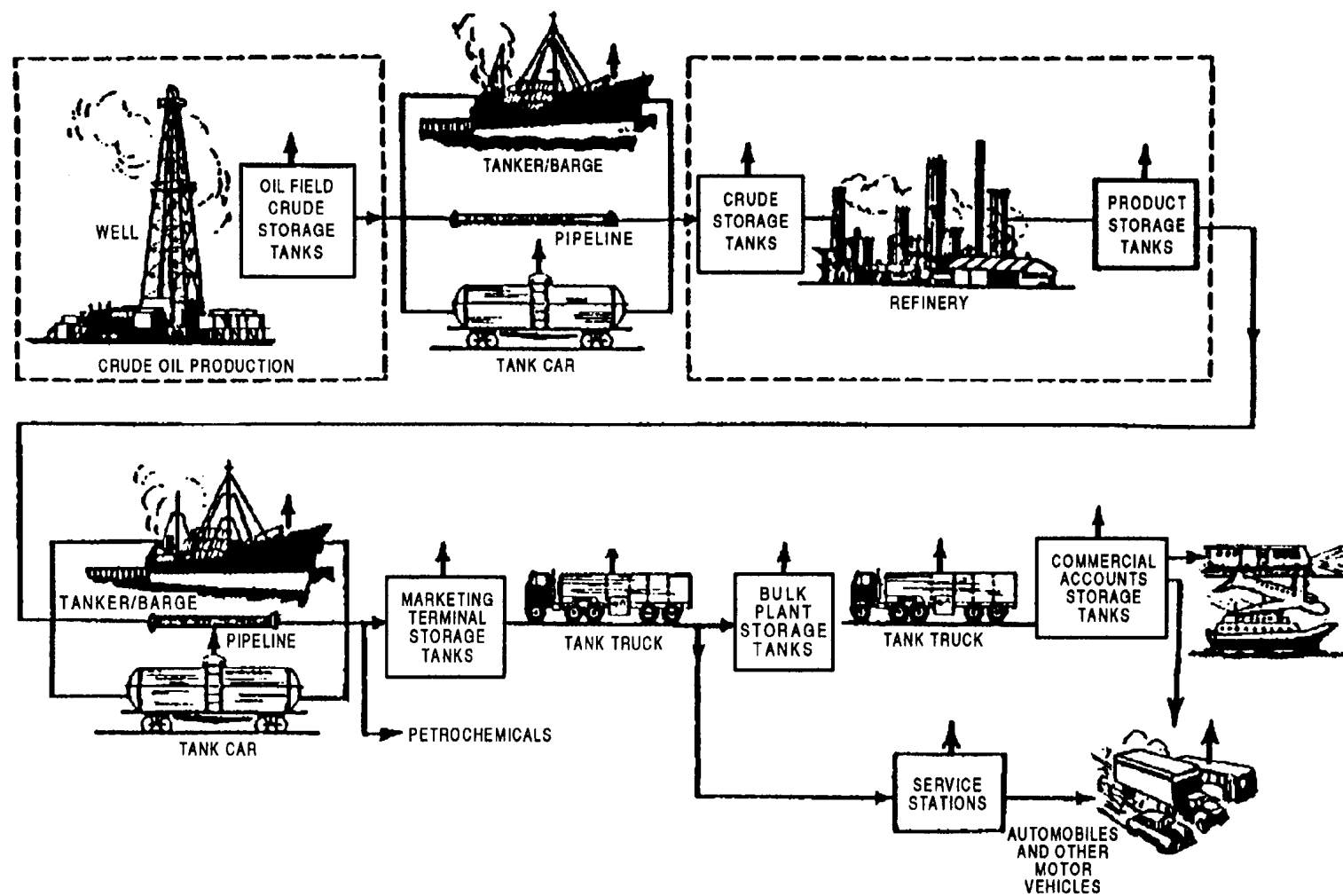


Figure 5.2-1. Flow sheet of petroleum production, refining, and distribution systems.  
(Points of organic emissions are indicated by vertical arrows.)

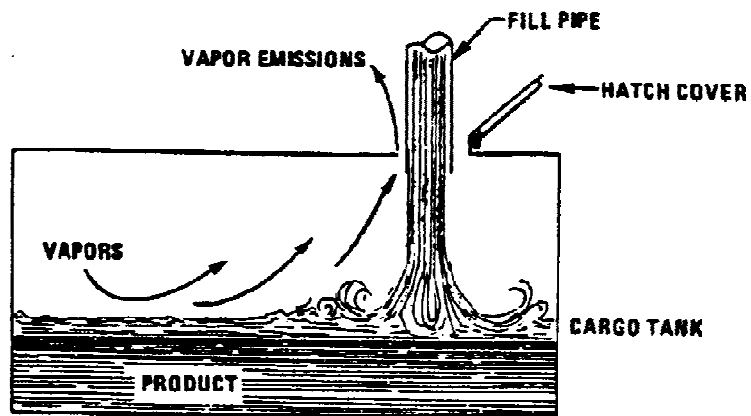


Figure 5.2-2. Splash loading method.

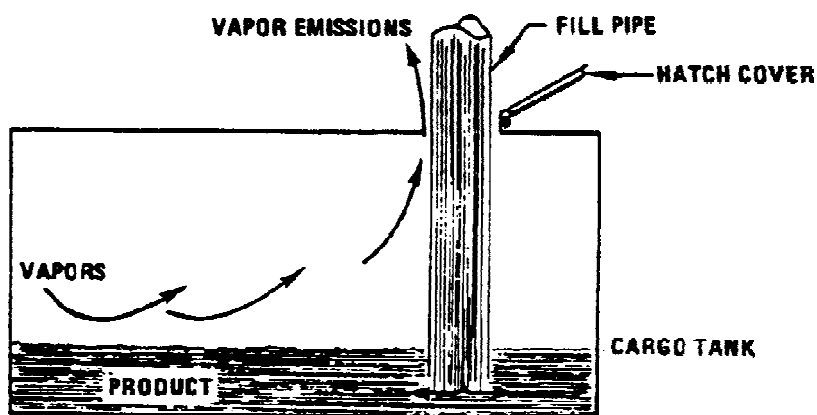


Figure 5.2-3. Submerged fill pipe.

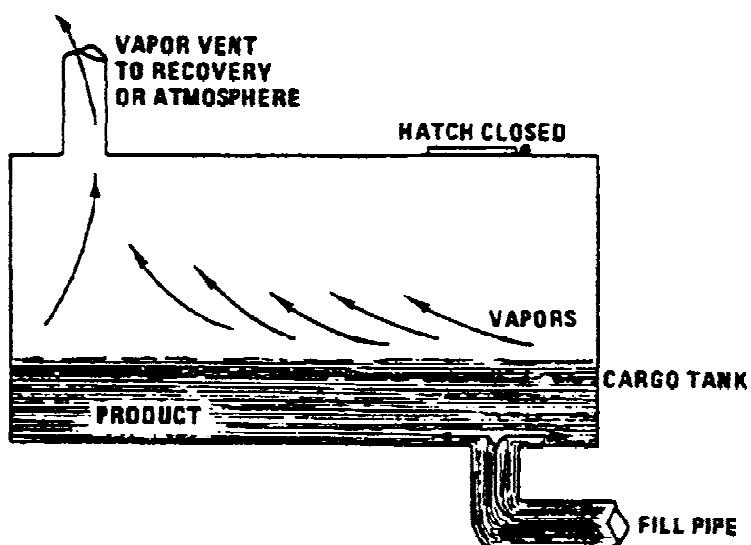


Figure 5.2-4. Bottom loading.

loading operation, resulting in high levels of vapor generation and loss. If the turbulence is great enough, liquid droplets will be entrained in the vented vapors.

A second method of loading is submerged loading. Two types are the submerged fill pipe method and the bottom loading method. In the submerged fill pipe method, the fill pipe extends almost to the bottom of the cargo tank. In the bottom loading method, a permanent fill pipe is attached to the cargo tank bottom. During most of submerged loading by both methods, the fill pipe opening is below the liquid surface level. Liquid turbulence is controlled significantly during submerged loading, resulting in much lower vapor generation than encountered during splash loading.

The recent loading history of a cargo carrier is just as important a factor in loading losses as the method of loading. If the carrier has carried a nonvolatile liquid such as fuel oil, or has just been cleaned, it will contain vapor-free air. If it has just carried gasoline and has not been vented, the air in the carrier tank will contain volatile organic vapors, which will be expelled during the loading operation along with newly generated vapors.

Cargo carriers are sometimes designated to transport only one product, and in such cases are practicing "dedicated service". Dedicated gasoline cargo tanks return to a loading terminal containing air fully or partially saturated with vapor from the previous load. Cargo tanks may also be "switch loaded" with various products, so that a nonvolatile product being loaded may expel the vapors remaining from a previous load of a volatile product such as gasoline. These circumstances vary with the type of cargo tank and with the ownership of the carrier, the petroleum liquids being transported, geographic location, and season of the year.

One control measure for vapors displaced during liquid loading is called "vapor balance service", in which the cargo tank retrieves the vapors displaced during product unloading at bulk plants or service stations and transports the vapors back to the loading terminal. Figure 5.2-5 shows a tank truck in vapor balance service filling a service station underground tank and taking on displaced gasoline vapors for return to the terminal. A cargo tank returning to a bulk terminal in vapor balance service normally is saturated with organic vapors, and the presence of these vapors at the start of submerged loading of the tanker truck results in greater loading losses than encountered during nonvapor balance, or "normal", service. Vapor balance service is usually not practiced with marine vessels, although some vessels practice emission control by means of vapor transfer within their own cargo tanks during ballasting operations, discussed below.

Emissions from loading petroleum liquid can be estimated (with a probable error of  $\pm 30$  percent)<sup>4</sup> using the following expression:

$$L_L = 12.46 \frac{SPM}{T} \quad (1)$$

where:

$L_L$  = loading loss, pounds per 1000 gallons (lb/10<sup>3</sup> gal) of liquid loaded

$S$  = a saturation factor (see Table 5.2-1)

$P$  = true vapor pressure of liquid loaded, pounds per square inch absolute (psia)  
(see Figure 7.1-5, Figure 7.1-6, and Table 7.1-2)

$M$  = molecular weight of vapors, pounds per pound-mole (lb/lb-mole) (see Table 7.1-2)

$T$  = temperature of bulk liquid loaded, °R (°F + 460)

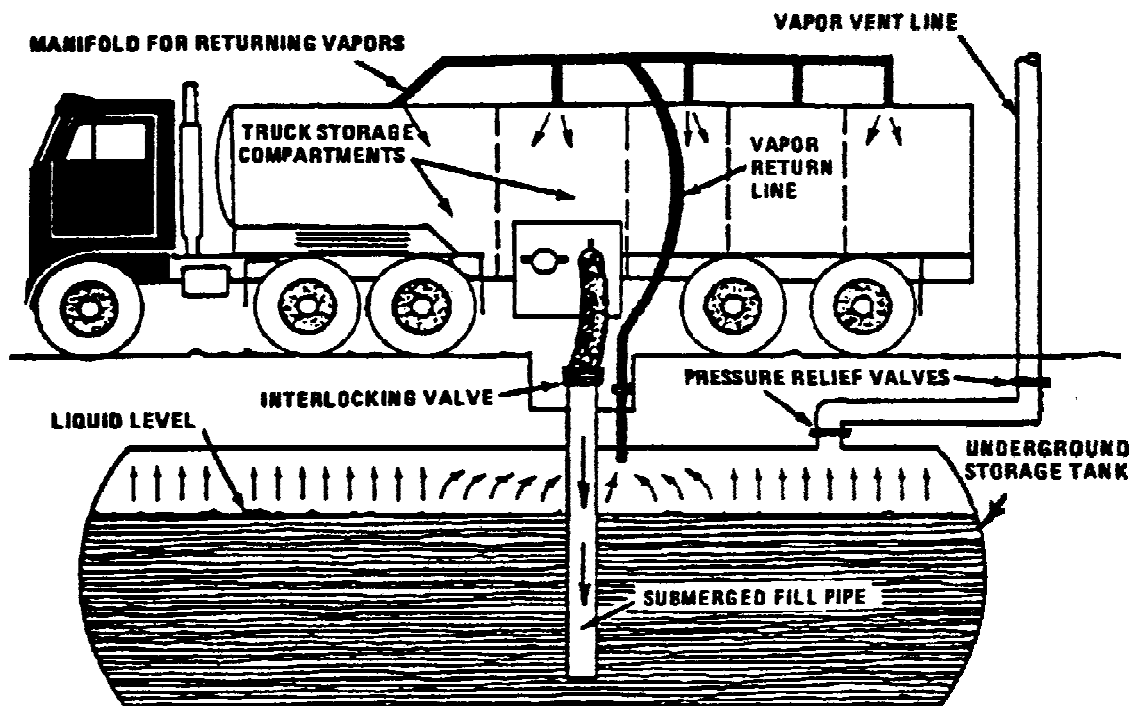


Figure 5.2-5. Tank truck unloading into a service station underground storage tank and practicing "vapor balance" form of emission control.

Table 5.2-1. SATURATION (S) FACTORS FOR CALCULATING PETROLEUM LIQUID LOADING LOSSES

Cargo Carrier	Mode Of Operation	S Factor
Tank trucks and rail tank cars	Submerged loading of a clean cargo tank	0.50
	Submerged loading: dedicated normal service	0.60
	Submerged loading: dedicated vapor balance service	1.00
	Splash loading of a clean cargo tank	1.45
	Splash loading: dedicated normal service	1.45
	Splash loading: dedicated vapor balance service	1.00
Marine vessels <sup>a</sup>	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

<sup>a</sup> For products other than gasoline and crude oil. For marine loading of gasoline, use factors from Table 5.2-2. For marine loading of crude oil, use Equations 2 and 3 and Table 5.2-3.

The saturation factor, S, represents the expelled vapor's fractional approach to saturation, and it accounts for the variations observed in emission rates from the different unloading and loading methods. Table 5.2-1 lists suggested saturation factors.

Emissions from controlled loading operations can be calculated by multiplying the uncontrolled emission rate calculated in Equation 1 by an overall reduction efficiency term:

$$\left(1 - \frac{\text{eff}}{100}\right)$$

The overall reduction efficiency should account for the capture efficiency of the collection system as well as both the control efficiency and any downtime of the control device. Measures to reduce loading emissions include selection of alternate loading methods and application of vapor recovery equipment. The latter captures organic vapors displaced during loading operations and recovers the vapors by the use of refrigeration, absorption, adsorption, and/or compression. The recovered product is piped back to storage. Vapors can also be controlled through combustion in a thermal oxidation unit, with no product recovery. Figure 5.2-6 demonstrates the recovery of gasoline vapors from tank trucks during loading operations at bulk terminals. Control efficiencies for the recovery units range from 90 to over 99 percent, depending on both the nature of the vapors and the type of control equipment used.<sup>5-6</sup> However, only 70 to 90 percent of the displaced vapors reach the control device, because of leakage from both the tank truck and collection system.<sup>6</sup> The collection efficiency should be assumed to be 90 percent for tanker trucks required to pass an annual leak test. Otherwise, 70 percent should be assumed.

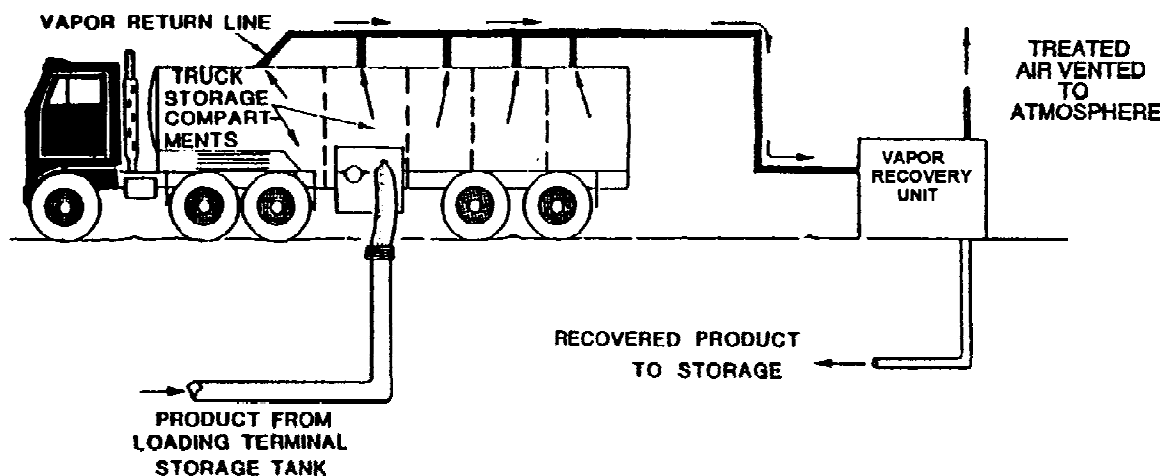


Figure 5.2-6. Tank truck loading with vapor recovery.

### Sample Calculation -

Loading losses ( $L_L$ ) from a gasoline tank truck in dedicated vapor balance service and practicing vapor recovery would be calculated as follows, using Equation 1:

### Design basis -

- Cargo tank volume is 8000 gal
- Gasoline Reid vapor pressure (RVP) is 9 psia
- Product temperature is 80°F
- Vapor recovery efficiency is 95 percent
- Vapor collection efficiency is 90 percent (for vessels passing annual leak test)

### Loading loss equation -

$$L_L = 12.46 \frac{SPM}{T} \left( 1 - \frac{\text{eff}}{100} \right)$$

where:

- S = saturation factor (see Table 5.2-1) - 1.00
- P = true vapor pressure of gasoline (see Figure 7.1-6) = 6.6 psia
- M = molecular weight of gasoline vapors (see Table 7.1-2) = 66
- T = temperature of gasoline = 540°R
- eff = overall reduction efficiency (95 percent control x 90 percent collection) = 85 percent

$$\begin{aligned} L_L &= 12.46 \frac{(1.00)(6.6)(66)}{540} \left( 1 - \frac{85}{100} \right) \\ &= 1.5 \text{ lb}/10^3 \text{ gal} \end{aligned}$$

Total loading losses are:

$$(1.5 \text{ lb}/10^3 \text{ gal})(8.0 \times 10^3 \text{ gal}) = 12 \text{ pounds (lb)}$$

Measurements of gasoline loading losses from ships and barges have led to the development of emission factors for these specific loading operations.<sup>7</sup> These factors are presented in Table 5.2-2 and should be used instead of Equation 1 for gasoline loading operations at marine terminals. Factors are expressed in units of milligrams per liter (mg/L) and pounds per 1000 gallons (lb/10<sup>3</sup> gal).

Table 5.2-2 (Metric And English Units). VOLATILE ORGANIC COMPOUND (VOC) EMISSION FACTORS FOR GASOLINE LOADING OPERATIONS AT MARINE TERMINALS<sup>a</sup>

Vessel Tank Condition	Previous Cargo	Ships/Ocean Barges <sup>b</sup>		Barges <sup>b</sup>	
		mg/L Transferred	lb/10 <sup>3</sup> gal Transferred	mg/L Transferred	lb/10 <sup>3</sup> gal Transferred
Uncleaned	Volatile <sup>c</sup>	315	2.6	465	3.9
Ballasted	Volatile	205	1.7	— <sup>d</sup>	— <sup>d</sup>
Cleaned	Volatile	180	1.5	ND	ND
Gas-freed	Volatile	85	0.7	ND	ND
Any condition	Nonvolatile	85	0.7	ND	ND
Gas-freed	Any cargo	ND	ND	245	2.0
Typical overall situation <sup>e</sup>	Any cargo	215	1.8	410	3.4

<sup>a</sup> References 2,8. Factors are for both VOC emissions (which excludes methane and ethane) and total organic emissions, because methane and ethane have been found to constitute a negligible weight fraction of the evaporative emissions from gasoline. ND = no data.

<sup>b</sup> Ocean barges (tank compartment depth about 12.2 m [40 ft]) exhibit emission levels similar to tank ships. Shallow draft barges (compartment depth 3.0 to 3.7 m [10 to 12 ft]) exhibit higher emission levels.

<sup>c</sup> Volatile cargoes are those with a true vapor pressure greater than 10 kilopascals (kPa) (1.5 psia).

<sup>d</sup> Barges are usually not ballasted.

<sup>e</sup> Based on observation that 41% of tested ship compartments were uncleaned, 11% ballasted, 24% cleaned, and 24% gas-freed. For barges, 76% were uncleaned.

In addition to Equation 1, which estimates emissions from the loading of petroleum liquids, Equation 2 has been developed specifically for estimating emissions from the loading of crude oil into ships and ocean barges:

$$C_L = C_A + C_G \quad (2)$$

where:

$C_L$  = total loading loss, lb/10<sup>3</sup> gal of crude oil loaded

$C_A$  = arrival emission factor, contributed by vapors in the empty tank compartment before loading, lb/10<sup>3</sup> gal loaded (see Note below)

$C_G$  = generated emission factor, contributed by evaporation during loading, lb/10<sup>3</sup> gal loaded

Note: Values of  $C_A$  for various cargo tank conditions are listed in Table 5.2-3.



5.2-3 (English Units). AVERAGE ARRIVAL EMISSION FACTORS,  $C_A$ , FOR CRUDE OIL LOADING EMISSION EQUATION<sup>a</sup>

Ship/Ocean Barge Tank Condition	Previous Cargo	Arrival Emission Factor, lb/10 <sup>3</sup> gal
Uncleaned	Volatile <sup>b</sup>	0.86
Ballasted	Volatile	0.46
Cleaned or gas-freed	Volatile	0.33
Any condition	Nonvolatile	0.33

<sup>a</sup> Arrival emission factors ( $C_A$ ) to be added to generated emission factors ( $C_G$ ) calculated in Equation 3 to produce total crude oil loading loss ( $C_L$ ). Factors are for total organic compounds; VOC emission factors average about 15% lower, because VOC does not include methane or ethane.

<sup>b</sup> Volatile cargoes are those with a true vapor pressure greater than 10 kPa (1.5 psia).

This equation was developed empirically from test measurements of several vessel compartments.<sup>7</sup> The quantity  $C_G$  can be calculated using Equation 3:

$$C_G = 1.84 (0.44 P - 0.42) \frac{M G}{T} \quad (3)$$

where:

- P = true vapor pressure of loaded crude oil, psia (see Figure 7.1-5 and Table 7.1-2)
- M = molecular weight of vapors, lb/lb-mole (see Table 7.1-2)
- G = vapor growth factor = 1.02 (dimensionless)
- T = temperature of vapors, °R (°F + 460)

Emission factors derived from Equation 3 and Table 5.2-3 represent total organic compounds. Volatile organic compound (VOC) emission factors (which exclude methane and ethane because they are exempted from the regulatory definition of "VOC") for crude oil vapors have been found to range from approximately 55 to 100 weight percent of these total organic factors. When specific vapor composition information is not available, the VOC emission factor can be estimated by taking 85 percent of the total organic factor.<sup>3</sup>

#### 5.2.2.1.2 Ballasting Losses -

Ballasting operations are a major source of evaporative emissions associated with the unloading of petroleum liquids at marine terminals. It is common practice to load several cargo tank compartments with sea water after the cargo has been unloaded. This water, termed "ballast", improves the stability of the empty tanker during the subsequent voyage. Although ballasting practices vary, individual cargo tanks are ballasted typically about 80 percent, and the total vessel 15 to 40 percent, of capacity. Ballasting emissions occur as vapor-laden air in the "empty" cargo tank is displaced to the atmosphere by ballast water being pumped into the tank. Upon arrival at a loading port, the ballast water is pumped from the cargo tanks before the new cargo is loaded. The ballasting of cargo tanks reduces the quantity of vapors returning in the empty tank, thereby reducing the quantity of vapors emitted during subsequent tanker loading. Regulations administered by the U. S. Coast Guard require that, at marine terminals located in ozone nonattainment areas, large tankers with crude oil washing systems contain the organic vapors from ballasting.<sup>9</sup> This is accomplished principally by displacing the vapors during

ballasting into a cargo tank being simultaneously unloaded. In other areas, marine vessels emit organic vapors directly to the atmosphere.

Equation 4 has been developed from test data to calculate the ballasting emissions from crude oil ships and ocean barges<sup>7</sup>:

$$L_B = 0.31 + 0.20 P + 0.01 PU_A \quad (4)$$

where:

- $L_B$  = ballasting emission factor, lb/10<sup>3</sup> gal of ballast water
- $P$  = true vapor pressure of discharged crude oil, psia (see Figure 7.1-5 and Table 7.1-2)
- $U_A$  = arrival cargo true ullage, before dockside discharge, measured from the deck, feet;  
(the term "ullage" here refers to the distance between the cargo surface level and the deck level)

Table 5.2-4 lists average total organic emission factors for ballasting into uncleaned crude oil cargo compartments. The first category applies to "full" compartments wherein the crude oil true ullage just before cargo discharge is less than 1.5 meters (m) (5 ft). The second category applies to lightered, or short-loaded, compartments (part of cargo previously discharged, or original load a partial fill), with an arrival true ullage greater than 1.5 m (5 ft). It should be remembered that these tabulated emission factors are examples only, based on average conditions, to be used when crude oil vapor pressure is unknown. Equation 4 should be used when information about crude oil vapor pressure and cargo compartment condition is available. The following sample calculation illustrates the use of Equation 4.

5.2-4 (Metric And English Units). TOTAL ORGANIC EMISSION FACTORS  
FOR CRUDE OIL BALLASTING<sup>a</sup>

Compartment Condition Before Cargo Discharge	Average Emission Factors			
	By Category		Typical Overall <sup>b</sup>	
	mg/L Ballast Water	lb/10 <sup>3</sup> gal Ballast Water	mg/L Ballast Water	lb/10 <sup>3</sup> gal Ballast Water
Fully loaded <sup>c</sup>	111	0.9	129	1.1
Lightered or previously short loaded <sup>d</sup>	171	1.4		

<sup>a</sup> Assumes crude oil temperature of 16°C (60°F) and RVP of 34 kPa (5 psia). VOC emission factors average about 85% of these total organic factors, because VOCs do not include methane or ethane.

<sup>b</sup> Based on observation that 70% of tested compartments had been fully loaded before ballasting. May not represent average vessel practices.

<sup>c</sup> Assumed typical arrival ullage of 0.6 m (2 ft).

<sup>d</sup> Assumed typical arrival ullage of 6.1 m (20 ft).

### Sample Calculation -

Ballasting emissions from a crude oil cargo ship would be calculated as follows, using Equation 4:

#### Design basis -

- Vessel and cargo description: 80,000 dead-weight-ton tanker, crude oil capacity 500,000 barrels (bbl); 20 percent of the cargo capacity is filled with ballast water after cargo discharge. The crude oil has an RVP of 6 psia and is discharged at 75°F.
- Compartment conditions: 70 percent of the ballast water is loaded into compartments that had been fully loaded to 2 ft ullage, and 30 percent is loaded into compartments that had been lightered to 15 ft ullage before arrival at dockside.

#### Ballasting emission equation -

$$L_B = 0.31 + 0.20 P + 0.01 P U_A$$

where:

- $P$  = true vapor pressure of crude oil (see Figure 7.1-5)  
= 4.6 psia  
 $U_A$  = true cargo ullage for the full compartments = 2 ft, and true cargo ullage for the lightered compartments = 15 ft

$$\begin{aligned} L_B &= 0.70 [0.31 + (0.20) (4.6) + (0.01) (4.6) (2)] \\ &\quad + 0.30 [0.31 + (0.20) (4.6) + (0.01) (4.6) (15)] \\ &= 1.5 \text{ lb}/10^3 \text{ gal} \end{aligned}$$

Total ballasting emissions are:

$$(1.5 \text{ lb}/10^3 \text{ gal}) (0.20) (500,000 \text{ bbl}) (42 \text{ gal/bbl}) = 6,300 \text{ lb}$$

Since VOC emissions average about 85 percent of these total organic emissions, emissions of VOCs are about:  $(0.85)(6,300 \text{ lb}) = 5,360 \text{ lb}$

#### 5.2.2.1.3 Transit Losses -

In addition to loading and ballasting losses, losses occur while the cargo is in transit. Transit losses are similar in many ways to breathing losses associated with petroleum storage (see Section 7.1, "Organic Liquid Storage Tanks"). Experimental tests on ships and barges<sup>4</sup> have indicated that transit losses can be calculated using Equation 5:

$$L_T = 0.1 P W \tag{5}$$

where:

$L_T$  = transit loss from ships and barges, lb/week- $10^3$  gal transported

$P$  = true vapor pressure of the transported liquid, psia (see Figure 7.1-5, Figure 7.1-6, and Table 7.1-2)

$W$  = density of the condensed vapors, lb/gal (see Table 7.1-2)

Emissions from gasoline truck cargo tanks during transit have been studied by a combination of theoretical and experimental techniques, and typical emission values are presented in Table 5.2-5.<sup>10-11</sup> Emissions depend on the extent of venting from the cargo tank during transit, which in turn depends on the vapor tightness of the tank, the pressure relief valve settings, the pressure in the tank at the start of the trip, the vapor pressure of the fuel being transported, and the degree of fuel vapor saturation of the space in the tank. The emissions are not directly proportional to the time spent in transit. If the vapor leakage rate of the tank increases, emissions increase up to a point, and then the rate changes as other determining factors take over. Truck tanks in dedicated vapor balance service usually contain saturated vapors, and this leads to lower emissions during transit because no additional fuel evaporates to raise the pressure in the tank to cause venting. Table 5.2-5 lists "typical" values for transit emissions and "extreme" values that could occur in the unlikely event that all determining factors combined to cause maximum emissions.

Table 5.2-5 (Metric And English Units). TOTAL UNCONTROLLED ORGANIC EMISSION FACTORS FOR PETROLEUM LIQUID RAIL TANK CARS AND TANK TRUCKS

Emission Source	Gasoline <sup>a</sup>	Crude Oil <sup>b</sup>	Jet Naphtha (JP-4)	Jet Kerosene	Distillate Oil No. 2	Residual Oil No. 6
Loading operations <sup>c</sup>						
Submerged loading - Dedicated normal service <sup>d</sup>						
mg/L transferred	590	240	180	1.9	1.7	0.01
lb/ $10^3$ gal transferred	5	2	1.5	0.016	0.014	0.0001
Submerged loading - Vapor balance service <sup>d</sup>						
mg/L transferred	980	400	300	— <sup>e</sup>	— <sup>e</sup>	— <sup>e</sup>
lb/ $10^3$ gal transferred	8	3	2.5	— <sup>e</sup>	— <sup>e</sup>	— <sup>e</sup>
Splash loading - Dedicated normal service						
mg/L transferred	1,430	580	430	5	4	0.03
lb/ $10^3$ gal transferred	12	5	4	0.04	0.03	0.0003
Splash loading - Vapor balance service						
mg/L transferred	980	400	300	— <sup>e</sup>	— <sup>e</sup>	— <sup>e</sup>
lb/ $10^3$ gal transferred	8	3	2.5	— <sup>e</sup>	— <sup>e</sup>	— <sup>e</sup>

Table 5.2-5 (cont.).

Emission Source	Gasoline <sup>a</sup>	Crude Oil <sup>b</sup>	Jet Naphtha (JP-4)	Jet Kerosene	Distillate Oil No. 2	Residual Oil No. 6
Transit losses						
Loaded with product						
mg/L transported						
Typical	0 - 1.0	ND	ND	ND	ND	ND
Extreme	0 - 9.0	ND	ND	ND	ND	ND
lb/10 <sup>3</sup> gal transported						
Typical	0 - 0.01	ND	ND	ND	ND	ND
Extreme	0 - 0.08	ND	ND	ND	ND	ND
Return with vapor						
mg/L transported						
Typical	0 - 13.0	ND	ND	ND	ND	ND
Extreme	0 - 44.0	ND	ND	ND	ND	ND
lb/10 <sup>3</sup> gal transported						
Typical	0 - 0.11	ND	ND	ND	ND	ND
Extreme	0 - 0.37	ND	ND	ND	ND	ND

<sup>a</sup> Reference 2. Gasoline factors represent emissions of VOC as well as total organics, because methane and ethane constitute a negligible weight fraction of the evaporative emissions from gasoline. VOC factors for crude oil can be assumed to be 15% lower than the total organic factors, to account for the methane and ethane content of crude oil evaporative emissions. All other products should be assumed to have VOC factors equal to total organics. The example gasoline has an RVP of 69 kPa (10 psia). ND = no data.

<sup>b</sup> The example crude oil has an RVP of 34 kPa (5 psia).

<sup>c</sup> Loading emission factors are calculated using Equation 1 for a dispensed product temperature of 16°C (60°F).

<sup>d</sup> Reference 2.

<sup>e</sup> Not normally used.

In the absence of specific inputs for Equations 1 through 5, the typical evaporative emission factors presented in Tables 5.2-5 and 5.2-6 should be used. It should be noted that, although the crude oil used to calculate the emission values presented in these tables has an RVP of 5, the RVP of crude oils can range from less than 1 up to 10. Similarly, the RVP of gasolines ranges from 7 to 13. In areas where loading and transportation sources are major factors affecting air quality, it is advisable to obtain the necessary parameters and to calculate emission estimates using Equations 1 through 5.

#### 5.2.2.2 Service Stations -

Another major source of evaporative emissions is the filling of underground gasoline storage tanks at service stations. Gasoline is usually delivered to service stations in 30,000-liter (8,000-gal) tank trucks or smaller account trucks. Emissions are generated when gasoline vapors in the

Table 5.2-6 (Metric And English Units). TOTAL ORGANIC EMISSION FACTORS  
FOR PETROLEUM MARINE VESSEL SOURCES<sup>a</sup>

Emission Source	Gasoline <sup>b</sup>	Crude Oil <sup>c</sup>	Jet Naphtha (JP-4)	Jet Kerosene	Distillate Oil No. 2	Residual Oil No. 6
Loading operations						
Ships/ocean barges						
mg/L transferred	— <sup>d</sup>	73	60	0.63	0.55	0.004
lb/10 <sup>3</sup> gal transferred	— <sup>d</sup>	0.61	0.50	0.005	0.005	0.00004
Barges						
mg/L transferred	— <sup>d</sup>	120	150	1.60	1.40	0.011
lb/10 <sup>3</sup> gal transferred	— <sup>d</sup>	1.0	1.2	0.013	0.012	0.00009
Tanker ballasting						
mg/L ballast water	100	— <sup>e</sup>	ND	ND	ND	ND
lb/10 <sup>3</sup> gal ballast water	0.8	— <sup>e</sup>	ND	ND	ND	ND
Transit						
mg/week-L transported	320	150	84	0.60	0.54	0.003
lb/week-10 <sup>3</sup> gal transported	2.7	1.3	0.7	0.005	0.005	0.00003

<sup>a</sup> Factors are for a dispensed product of 16°C (60°F). ND = no data.

<sup>b</sup> Factors represent VOC as well as total organic emissions, because methane and ethane constitute a negligible fraction of gasoline evaporative emissions. All products other than crude oil can be assumed to have VOC factors equal to total organic factors. The example gasoline has an RVP of 69 kPa (10 psia).

<sup>c</sup> VOC emission factors for a typical crude oil are 15% lower than the total organic factors shown, in order to account for methane and ethane. The example crude oil has an RVP of 34 kPa (5 psia).

<sup>d</sup> See Table 5.2-2 for these factors.

<sup>e</sup> See Table 5.2-4 for these factors.

underground storage tank are displaced to the atmosphere by the gasoline being loaded into the tank. As with other loading losses, the quantity of loss in service station tank filling depends on several variables, including the method and rate of filling, the tank configuration, and the gasoline temperature, vapor pressure and composition. An average emission rate for submerged filling is 880 mg/L (7.3 lb/1000 gal) of transferred gasoline, and the rate for splash filling is 1380 mg/L (11.5 lb/1000 gal) transferred gasoline (see Table 5.2-7).<sup>5</sup>

Emissions from underground tank filling operations at service stations can be reduced by the use of a vapor balance system such as in Figure 5.2-5 (termed Stage I vapor control). The vapor balance system employs a hose that returns gasoline vapors displaced from the underground tank to the tank truck cargo compartments being emptied. The control efficiency of the balance system ranges from 93 to 100 percent. Organic emissions from underground tank filling operations at a service station employing a vapor balance system and submerged filling are not expected to exceed 40 mg/L (0.3 lb/1000 gal) of transferred gasoline.

Table 5.2-7 (Metric And English Units). EVAPORATIVE EMISSIONS FROM GASOLINE SERVICE STATION OPERATIONS<sup>a</sup>

Emission Source	Emission Rate	
	mg/L Throughput	lb/10 <sup>3</sup> gal Throughput
Filling underground tank (Stage I)		
Submerged filling	880	7.3
Splash filling	1,380	11.5
Balanced submerged filling	40	0.3
Underground tank breathing and emptying <sup>b</sup>	120	1.0
Vehicle refueling operations (Stage II)		
Displacement losses (uncontrolled) <sup>c</sup>	1,320	11.0
Displacement losses (controlled)	132	1.1
Spillage	80	0.7

<sup>a</sup> Factors are for VOC as well as total organic emissions, because of the methane and ethane content of gasoline evaporative emissions is negligible.

<sup>b</sup> Includes any vapor loss between underground tank and gas pump.

<sup>c</sup> Based on Equation 6, using average conditions.

A second source of vapor emissions from service stations is underground tank breathing. Breathing losses occur daily and are attributable to gasoline evaporation and barometric pressure changes. The frequency with which gasoline is withdrawn from the tank, allowing fresh air to enter to enhance evaporation, also has a major effect on the quantity of these emissions. An average breathing emission rate is 120 mg/L (1.0 lb/1000 gal) of throughput.

#### 5.2.2.3 Motor Vehicle Refueling -

Service station vehicle refueling activity also produces evaporative emissions. Vehicle refueling emissions come from vapors displaced from the automobile tank by dispensed gasoline and from spillage. The quantity of displaced vapors depends on gasoline temperature, auto tank temperature, gasoline RVP, and dispensing rate. Equation 6 can be used to estimate uncontrolled displacement losses from vehicle refueling for a particular set of conditions.<sup>13</sup>

$$E_R = 264.2 [(-5.909) - 0.0949 (\Delta T) + 0.0884 (T_D) + 0.485 (RVP)] \quad (6)$$

where:

$E_R$  = refueling emissions, mg/L

$\Delta T$  = difference between temperature of fuel in vehicle tank and temperature of dispensed fuel, °F

$T_D$  = temperature of dispensed fuel, °F

RVP = Reid vapor pressure, psia

Note that this equation and the spillage loss factor are incorporated into the *MOBILE* model. The *MOBILE* model allows for disabling of this calculation if it is desired to include these emissions in the stationary area source portion of an inventory rather than in the mobile source portion. It is estimated that the uncontrolled emissions from vapors displaced during vehicle refueling average 1320 mg/L (11.0 lb/1000 gal) of dispensed gasoline.<sup>5,12</sup>

Spillage loss is made up of contributions from prefill and postfill nozzle drip and from spit-back and overflow from the vehicles's fuel tank filler pipe during filling. The amount of spillage loss can depend on several variables, including service station business characteristics, tank configuration, and operator techniques. An average spillage loss is 80 mg/L (0.7 lb/1000 gal) of dispensed gasoline.<sup>5,12</sup>

Control methods for vehicle refueling emissions are based on conveying the vapors displaced from the vehicle fuel tank to the underground storage tank vapor space through the use of a special hose and nozzle, as depicted in Figure 5.2-7 (termed Stage II vapor control). In "balance" vapor control systems, the vapors are conveyed by natural pressure differentials established during refueling. In "vacuum assist" systems, the conveyance of vapors from the auto fuel tank to the underground storage tank is assisted by a vacuum pump. Tests on a few systems have indicated overall systems control efficiencies in the range of 88 to 92 percent.<sup>5,12</sup> When inventorying these emissions as an area source, rule penetration and rule effectiveness should also be taken into account. *Procedures For Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81-026d, provides more detail on this.

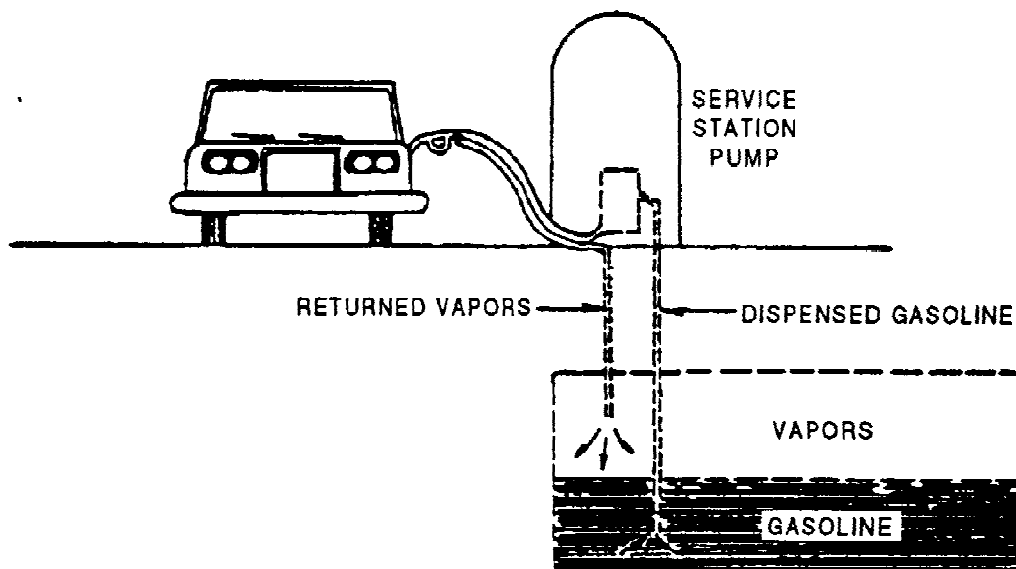


Figure 5.2-7. Automobile refueling vapor recovery system.

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